

Chapter 5

The Implementation and Effectiveness of GIS in Secondary Education: Case Studies Inside Three High Schools

Introduction

The experiments (Chapter 4) showed that GIS was most often effective in increasing student scores on inquiry-based lessons, but it was less effective in raising scores on standardized tests. This analysis illustrated the limitations of such quantitative measures to assess the effectiveness of GIS as a technology and method. In order to more fully and accurately understand the effectiveness of GIS in education, a qualitative set of case studies at the same three high schools was conducted. These case studies also supplement the national survey to answer *how and why* teachers implement GIS by focusing on specific teachers in these schools. What does a classroom look like where the teacher has decided to implement GIS—in terms of teaching, learning, and meaning constructed? These case studies are the subject of this chapter.

Methodology

Case studies can illustrate causes, subtleties, and complexities (Adelman et al. 1980: 59), are flexible, and create authentic and understandable knowledge (Roberts 1996), particularly for teachers (Stenhouse 1985). A limitation of the data from the national GIS in education survey is that they were self-reported, in the teachers' own

words. Case study data provide an account from the author's perspective as well as the teachers' perspective. A limitation of the experiments is that full assessments should include thinking, information processing, communication, creativity, participation, and involvement (Moser and Hanson 1996). Without a case study methodology, several of these criteria cannot be evaluated. The case studies were interpretivist in design, aimed at understanding the meaning given to phenomena by the author, the teachers, and the students. Case studies at Riparian, Hope, and Prairie Vista took place at the same time as the experiments, so control groups and experimental groups could be observed. In addition, I observed students in an after-school, year-long class called "Technological Careers in Geography" (TCIG) at Prairie Vista.

The case studies employed the participant observation method of research, central to many ethnographic studies that examine the culture of teachers and their classrooms (Wolcott 1997). The author was an active participant and observer, creating (or co-creating with the teacher) these lesson modules, providing technical assistance to the laboratory managers, teachers, and students, and interviewing teachers and students in formal and informal settings. Although my presence in these classrooms undoubtedly altered some interaction among the students, by observing both the control groups and the experimental groups, comparisons can be made from a rich account.

Case studies were scheduled prior to the beginning of the 1998-1999 school year. Prior to the case studies, the author discussed the goals for the research with each teacher. A tentative schedule for observation and implementation of GIS and traditional lessons was agreed to in advance. All lessons were reviewed by the teachers before implementation. Care was taken to avoid scheduling lessons on the

same day at more than one site, so that I could observe as many lessons as possible in each school.

Case studies relied on personal interviews, formal and informal written and oral end-of-semester surveys, and participant observation. Interviews with students who participated in the experiment included questions about what the student liked and disliked about GIS, suggestions for improving the GIS-based lessons, whether the student would like to use GIS again, how GIS affected the student's learning of the lesson's concepts, if and how GIS affected the classroom dynamics, the questions the student had about GIS, and whether the student would like to use GIS on the job. These interviews were conducted informally, when questions would not disrupt the student's progress with the lesson, typically before or after the class session.

End-of-semester written surveys were administered to assess beliefs and affective, or attitudinal, learning. Students commented on the utility of different tools they used during the semester, including GIS, and about how their attitude about geography had changed as a result of the class, as well as other topics that will be discussed in this chapter.

Participant observation was conducted using the following guidelines. The reactions of the students to the inquiry-based methods were carefully observed and compared between control and experimental groups. I studied the problem-solving approaches of both groups, noting the types of questions posed by the students in each. Interactions among students and between students and teachers within each group were examined. I made handwritten observations as I worked with students through each exercise. I used no recording devices until I was alone after school, to avoid disrupting communication by making students feel uncomfortable during class.

Interviews with the teachers who participated in the experiment were conducted more formally than those with the students, before and after the

experiments took place. Besides questions about the teachers' background—the results of which are reported in Chapter 4—questions were asked about the teachers' beliefs about instruction, about geography, and how they would characterize their teaching style. Several questions came from the national survey for comparative purposes, such as the support of the school administration for geography and for technology within geography. Other questions were asked about the school's technical support, what the teachers' major instructional methods were, what they liked and disliked about GIS, whether they foresaw themselves using it again, and suggestions for improving the GIS-based lesson modules. Teachers were also asked whether the use of GIS affected classroom teaching, learning, and dynamics. From interviewing each teacher, I was able to understand the human networks the teacher established when implementing GIS in the classroom, for data, technical support, funding, and curricular implementation. I also asked the teachers what they believed to be the most important technical, pedagogical, and administrative methods and issues of implementing GIS technology in geography. To supplement the experimental data, questions were asked about the teachers' opinion of the effectiveness of implementing GIS, particularly with regards to the standards. Each teacher was asked his or her opinion of the effectiveness of the experiments and the future of GIS in geography education.

Case studies included an analysis of narratives, or written stories, from the teachers. According to Kyratzis and Green (1997) a narrative is “a type of text that involves past, present and future reference to an experience; it also contains a coherent and cohesive set of signs and symbols that members read and interpret” (p. 30). Doyle (1997) goes so far as to say that narratives are a “quite appropriate, if not the only, way of knowing teaching” (p. 95). The interpretation of narratives provided an additional set of data that will describe the experiences, attitudes, and feelings of the

participants using GIS. Through narrative, the student and teacher's motivation for action may be discovered, and teaching may be improved (Fenstermacher 1997).

For both the teachers and the students, observation took place over an entire academic year—before, during, and after the selected lessons were administered. Particular attention was paid to changes in instructional methods, motivation, activity level, patterns of communication, and final products over the course of the year. I spent approximately three weeks in each classroom during the year, and spent an additional two weeks working with the teachers before, after, and between semesters.

Next, the case study data were compared to the results of the national survey, in order to assess these schools in conjunction with GIS implementation and innovation diffusion models. Threaded throughout the chapter are comparisons to the experiments, in order to try to understand the reasons behind the empirical results.

I created all lessons—those using GIS and their traditional counterparts—alone or with one of the case study teachers. These lessons were assessed against the geography, social studies, and technology standards to determine if they were more effective in teaching standards-based concepts and skills than the lessons the teachers had been using prior to GIS. This research sought to test the hypothesis that GIS in an educational setting becomes a constructivist, inquiry-oriented tool. I assessed the degree of implementation and institutionalization of GIS in each school, and whether these teachers would use it after the case studies ended. These lessons were also examined as to whether they permanently changed the curriculum, or whether they were simply an aberration while the study was underway.

The amount and type of GIS use was analyzed by comparing it to the teacher's geography experience, teaching style, and support for geography and technology by the school and the school district. I identified significant challenges and catalysts in the success or failure of GIS to effect change in geography teaching and learning.

The remainder of this chapter is organized as follows. First, a description of a typical hour in one of the case study schools will serve to illustrate the successes and challenges of implementing this technology in the classroom. A topical description and analysis of GIS's implementation and effectiveness on students, learning, teachers, and instruction follows. Communication, special needs students, community linkages, professional development, attitudes, and pedagogical approach are addressed. Completing the chapter is an analysis of this implementation and effectiveness using several curricular and implementation models.

Case Study Analysis

An Hour In the Life of GIS in High School Geography

It is 12:50 p.m. in the Riparian High School Macintosh lab, and students will be here in 10 minutes to work on the *Earthquakes Everyday* GIS-based lesson. After one more check on a vacant computer, I discover that the earthquake data needed for today's lesson is nowhere to be found on the computer network. I try to attract the attention of Ms. Mu|oz, who as usual is answering technical questions from four students at once from somewhere inside a pile of computer manuals, diskettes, and motherboards. When she sees the distressed look on my face, she mobilizes the computer lab assistant to work with her on solving the problem, leaving a trail of students following in her wake. For some reason, even though the data were on the server last semester, and were there when I checked last week, they are now gone. While Ms. Mu|oz and her assistant find the backed up data and copy it from their server to each computer in the lab, I know that at this very moment, Mr. Stevenson is in his classroom, preparing his students for today's GIS-based lesson. As students currently in the lab are politely ushered out and the Geography students file in, Mr.

Stevenson passes out the lesson packet for the earthquakes unit and discusses its goals. As several students respond to his questions about why the study of natural hazards might be important, and name natural hazards that are common to Colorado, out of the corner of my eye, I see Ms. Mu|oz giving me the thumbs-up sign through the glass window of her office, beckoning me to test the data on one computer.

“Excuse me,” I say to two students at a terminal, “I need to check to ensure the data you’ll be using is there.” As quickly as the operating system allows, I check the appropriate directory for the data—plate boundaries, cities, countries, fault lines, earthquake epicenters for 1997—yes, all the files are there. To double check, I make sure it loads in *ArcView* GIS, and when it does, I close the program and tell the two students, “It’s all yours!,” breathing a sigh of relief that a crisis has been averted yet again.

Few students bother to read the text that the teacher and I so carefully wrote as an introduction to the unit. Rather, most open up the web browser to access the USGS site where current earthquakes are posted. “Remember, you must type it in exactly as it appears,” Mr. Stevenson and I tell the students. A few students need help cutting and pasting the list of current earthquakes into their favorite word processor—some use *SimpleText*, some use *Microsoft Word*, and some use *ClarisWorks*. Students must edit the pasted data to create a comma-delimited text file, and have to change coordinate values so that the western and southern hemisphere earthquake epicenters would read as negative longitude and latitude, respectively.

“Why are we editing this file?” a student asks me, and even though the teacher has explained the goals of the unit and they are written in the directions, I explain that they would soon be examining the temporal and spatial distribution of this week’s earthquakes on a set of digital maps. We discover that, for security reasons, the only

folder that students can save to is on the network, called "student temporary." This is a common folder for all students at the high school, and therefore is quickly becoming a huge list of files. The teacher and I caution the students to name their edited file with their team's name or some other distinguishing name, or else they will not be able to determine which file is theirs. I soon wish we had been more specific, however, because some students named their files with spaces and non-alphanumeric text, which we know will be a problem for the GIS software to read.

With 20 minutes left before class ends, some students have modified their earthquake file, while others are barely getting started. I see Mr. Stevenson on the other side of the room, and we occasionally consult about anything that could be improved in this lesson, and what students are having trouble with. Bringing the data into *ArcView* presents problems for some students because the edited file is in error, or they had saved it in non-text format. Some have to go back to the Internet for the data while they keep *ArcView* running. For one, the computer goes down and will require a four-minute reboot. "Avoid opening the web browser and the GIS software at the same time, because low memory makes the system crash!" we tell the students. By now, some students have transferred the data into the GIS software. "What should we do now?," they ask us. "Read the directions," we tell them almost in unison, and even help them find their place in the procedures. Students are reaching the analytical essay questions in the lesson. "You mean we have to answer these questions?," a few ask. Mr. Stevenson just nods and smiles.

By now, the person who was looking at the Denver Broncos web page is on task, and everyone seems engaged in the earthquake activity. Students are sitting in largely gender-specific groups. One male student came over to help a group of females, but largely is trying to impress them, succeeding only in being disruptive to their group and several around them. I am not deluged with questions at present, so

I try to observe what each group is doing. The lab's configuration and tight quarters make it extremely difficult to reach students in the northwest corner without disrupting students who are working on computers closer to us. Students in that corner are receiving less attention and look like they are wandering from the assignment.

Curiously, the corner has also attracted students who prefer to work independently and are now producing some of the best analyses in the class. They are already comparing this week's earthquakes to earthquakes from all of 1997, and to the location of cities and plate boundaries. Most students readily observe that the pattern of earthquakes adhere closely to plate boundaries. A few express amazement at how many earthquakes are recorded each day. Several students are changing symbols and attributes to map, and they are creating layouts containing maps, scales, and legends that will be plotted before the bell rings. Someone asks me how the earthquakes from all over the world can be recorded at the USGS National Earthquake Information Center in Golden, Colorado.

I make an announcement that a problem exists with the point symbols to plot the earthquake epicenters and cities—"just do the best you can with the alphanumeric symbols." This problem stems from network security that prohibits *ArcView* to write to the system fonts directory when it loads. The computer lab support staff are the only ones that have the necessary security privileges to fix it. It was fixed last semester, but it seems to have become a problem again when the data were reloaded just before class began.

One group of students confesses, "we don't want to read all these instructions; just tell us what to do." At least they are honest! Yet I try to generate some enthusiasm: "Usually, you are stuck with the scale, the data shown, and the symbology on a paper map in an atlas. Here, you have the capability of producing

your own map to answer the questions, just the way you want it.” Later, when they have created a map, this same group asks me what I think should be on the map. “It’s your map,” I tell them, “you should make it the way *you* want it, not how *I* want it.” Their faces attest to their disappointment in my answer. Having arrived this year from middle school, they are so used to being told what to do that it is difficult for them to think creatively. As the bell is about to ring, I am impressed by some of the maps and databases on computer screens around the room. Students working on the computers displaying the outstanding maps stay after class until the last minute before the bell rings for their *next* class. As the class period draws to a close, Mr. Stevenson’s voice can be heard above the printer that everyone is trying to print on at once: “Remember that we’ll be back here tomorrow, so you don’t have to get all this done today! And remember to save your project!” They’ll have to save to the big “student temporary” list—nobody has thought to bring any floppy disks.

As the above description demonstrates, teaching with GIS has an effect on teachers, teaching, students, and learning. The following topical analyses will analyze these effects and assess the implementation and effectiveness of GIS in the case study schools.

Development Implications

Before the *Earthquakes Everyday* lesson described above was implemented, the teacher and I spent significant time not only to develop the lesson, but to prepare the required digital spatial data. Similarly, teachers responding to the national survey indicated that developing their lessons and data required significant effort, often completed on the teachers’ personal time. Adding the 1970 and 1980 Census data to *The Hill* lesson required one day in the library, \$30 in copy fees, and three days to

enter the data into the GIS database. After gathering and processing the data, the lesson needed to be written, requiring another two days. Writing it for both the Macintosh and PC platforms added several more hours, and posting it to the Internet for ease of maintenance and printing for students required several days. I noted that students tended to do better when a small picture of the GIS tool or button required for a step was included as a visual aid in the instructions. Downloading and scanning pictures of these buttons and embedding them in each lesson's web page required another day's work. Both lessons *and* data are necessary for a teacher to use a GIS-based unit, and these data sets are often large and difficult to transfer between computers. The total development time for this unit now approached two weeks. The other lessons required a similar amount of time.

The large time commitment involved in developing GIS-based lessons provides one reason why few lessons have been developed, and consequently why few teachers are using GIS. Furthermore, it was discovered that developing traditional versions of GIS-based lessons was difficult, as many of the data sets are not available as maps or tables in text or atlas form. The only way to provide the control group with the county social area analysis data was to plot paper maps from a GIS, requiring \$165 worth of copies to be made for the students. Teachers wanting to use inquiry-based methods in a lesson written for GIS will find it difficult to use those lessons in a traditional environment for the same reasons. This will work *against* the spread of GIS-based methods to a wide educational audience.

Managing Classrooms

Time to Complete GIS-Based Lessons

In all cases, GIS-based lessons required more time for students to work through than their non-GIS counterparts, in large part because the non-GIS students

used tools they were already familiar with. The additional time required for GIS-based lessons presents a challenge for teachers confronted with the requirement of teaching breadth rather than depth. However, as all case study teachers pointed out, “faster is not necessarily better.” Teachers were emphatic that both groups learned the lesson content, but GIS students learned new skills in addition to the content, which concurred with my observations.

In *Earthquakes Everyday*, most control groups spent an entire class period plotting locations of epicenters on a paper map. Most experimental groups spent an entire class period reformatting the epicenters file from the Internet. This proved monotonous to students, but in the process, students learned how to change data from one format to another, how to use data from the Internet, and how to analyze data using two different computer applications. Students began discussing other spatial data on the Internet that could be analyzed in a GIS.

Case study teachers seemed to have flexibility in scheduling their lessons, even in the more rigid IB program. Because they valued GIS, they made room for it in the curriculum. The ideal situation for learning occurred with Hope High School’s block schedule, giving students over an hour and a half in each class. GIS, like any computer tool, requires at least five minutes to access at the beginning of class and to save and exit at the end of class. With traditional class periods, the sense is often that the students barely begin a project when the end-of-class bell rings.

Classroom Logistics

One GIS-based lesson was conducted in Riparian’s math lab, because of a scheduling conflict in the main computer lab. Although *ArcView* GIS was loaded, a problem with the marker fonts caused point symbols to only be displayed with alphanumeric characters, such as dollar signs and question marks. This made it very

difficult for the students to interpret cities, manufacturing and mining sites, and earthquakes. Because of the computer problems occurring in the lab, the students in Prairie Vista's TCIG class moved to the computer-aided drafting (CAD) that had more memory per computer. Unfortunately, the CAD lab's high-resolution plotter proved too slow (15 minutes per map) to plot maps from the GIS software. As a result, the students had no hard copy to show for their entire semester project. These examples illustrate that it is more difficult to move GIS-based instruction to different settings than traditional instruction.

Technical Ability, Capability, and Support

Computer Hardware

All three high schools in the case studies had extensive computer laboratory facilities. Only four states ranked above Colorado in the number of high-tech schools, according to a study by Market Data Retrieval (White 1997: 43). However, considering that these labs served the entire school, teachers had the same difficulties scheduling their classes as teachers responding to the national survey. Only at Hope High School were the computers better than the minimum requirement to handle the intensive memory, processing power, and storage of GIS software and data. In March 1997, Colorado's education technology plan called for the state to integrate technology with content standards and to take the lead in building the infrastructure for networked classrooms and schools (Walsh 1997). Hope's school district created a plan in which all schools lease their computers from the district, phased in on a five-year cycle. Up-to-date computers positively influenced the success of GIS in the school.

Riparian's computers barely met the minimum requirement, and were plagued by software crashes. Students learned not to run multiple applications concurrently, which presented a problem when they needed to download data from the Internet into

the GIS. Even though Spring 1999 marked the end of the third year of GIS at Riparian, technological problems still arose. The bulk of these problems involved transferring and using files over the network. Therefore, hardware issues are ever-present, forcing teachers to become technically proficient and requiring the assistance of a technical support staff. Difficulties in hardware were somewhat alleviated by the presence of two full-time computer support staff at Hope and Riparian.

Prairie Vista had by far the worst situation. The geography teacher was forced to use a small lab that was not staffed, and to make matters worse, the political situation in the school made obtaining hardware and software support extremely difficult.

Technical Ability of Teacher

All teachers were technically able to assist students in GIS. GIS was most rapidly implemented when the individual teacher, not just the school, had the software and sufficient hardware on which to run it. Ms. Cessna had both, and therefore, Hope implemented GIS more rapidly than the other two schools. Furthermore, only at Hope High School was the development platform used by the teacher (laptop) the same as that of the computer lab—they were both PC-based. Mr. Stevenson installed a home computer during the middle of the last semester of the case studies, but he still lacked a computer in his classroom or his office. Mr. Clark's office contained a computer he shared with other social studies teachers, but the computer did not have ArcView GIS software loaded on it.

Technical Support Staff

Because of the intensive memory, processing, and storage requirements of GIS software and data, the case studies emphatically demonstrated that the involvement of the computer lab manager is critical to the success of GIS in high school education. The computer lab manager troubleshoots hardware and software problems, freeing up time for the content teacher to design lessons. As discovered in the national survey, teachers using GIS are typically “on their own” in a school. Therefore, without a lab manager’s support, needs of teachers using GIS may be perceived as smaller and of lesser importance than those of a team of teachers, such as the entire math department.

Riparian High School was fortunate throughout these projects to have had the support of Ms. Mu|oz. Because Ms. Mu|oz taught numerous computer science classes in addition to her duties as lab manager, she understood the needs of teachers, students, and the requirements of the technology. During the first semester that GIS was used with *The Hill* project, *ArcView* GIS, which requires 32 megabytes of RAM, was run on 486-speed PCs with 8 megabytes of RAM. Despite the frequent system problems inherent with such a configuration, the project was successfully completed. During the following semester, the project was conducted on Pentium-based PCs. During the next year, the entire program was transferred to the Macintosh laboratory, and after some conversion problems, it proved as workable in this lab as in the PC lab. Even though the lessons had to be adjusted for the different platform, the computer lab manager had grown accustomed to working on GIS every semester. As the lab manager learned along with the teacher and students about the program, she became more interested in it, particularly in the potential for her computer science students to write programs in *Avenue*, the

computer language behind *ArcView* software. Ms. Mu|oz wanted to use computers for something besides programming, the Internet, and word processing, and the requirements of GIS enabled her to justify the necessary hardware in her subsequent grant proposals.

It is difficult for schools to compete with the salaries in business and higher education in keeping qualified technical support staff. Two computer support people came to and left Riparian during the single year of case studies. The difficulties discovered through the case studies would have been greatly compounded had Ms. Mu|oz left, because not only was she technically proficient, but she believed in the benefits of GIS.

Bringing lab managers “on board” is even more important than their technical proficiency for several reasons. First, GIS is difficult for a teacher to use GIS without computer lab support, as corroborated by the national survey. In the words of Mr. Stevenson, “for a teacher with limited computer knowledge, a room full of crashing computers can be quite intimidating!” Second, lab managers have a great deal of political power in determining how computer-based instruction works in the school. Third, because lab managers are extremely stretched for time, they are more inclined to make time for something they personally believe in.

Political Ramifications of GIS as a Computer-Based Tool

At times, intensive computer requirements of a teacher using GIS can cause workplace tensions between that teacher, the rest of the department, and the computer support staff. GIS-based teachers typically want to use every piece of available hardware—scanners, printers, and computers, store large amounts of data (such as 150-megabyte color digital orthophotoquads), and need supporting software

such as data compression programs and web browsers. Nowhere was this more evident than at Prairie Vista, where the computer lab manager would not permit the students to use part of a 9-gigabyte server's hard disk. Mr. Clark was able to convince another teacher to let him access that teacher's disk. His goal was to assemble a PC lab not only to run more GIS software extensions, but also so that he would have more control over the machines for his own students.

A National Geographic Society Education Foundation grant funded GIS software and training in two school districts, including the one where Hope High School is located. However, district support does not guarantee school support. A teacher in another school in the same district revealed that he wouldn't be able to run GIS at his school because "the lab manager won't load it."

Communication Patterns

Group Work

All students in the control groups worked in teams, while a few students worked alone in the experimental groups. Students in all experimental groups exhibited more communication than the control groups—primarily in discussing the analyses and offering help to other students. This sharing of knowledge is the result of distributed expertise in the classroom and is an indication of a constructivist-style classroom. In only one instance did this sharing prove disruptive, when a helper "took over" the keyboard from a group of students. Despite the fact that the control groups were quieter and appeared to be more on task, no teacher favored going back to traditional methods. After assessing these exercises, it appeared as though the teams performed worse than the few students who chose to work alone, which is directly opposite to much of the literature promoting the benefits of group work.

Most teams organized themselves by gender in both control and experimental classrooms. The few groups who tended to have difficulty getting started in the experimental group tended to be females, mainly because of a reluctance to read the lesson. No other gender differences in communication or ability to work with GIS were observed, which supports the lack of differences in scores by gender found in the experiments.

Lab Configuration

The control groups worked in teams by pulling their desks together. Since the primary setting for the GIS-based lessons was the computer laboratory, the lab's configuration was found to have a profound influence on communication, and thus on learning. Hope had the ideal set-up—spacious, with some room on the tables for students to write on their worksheets. As mentioned above, Riparian's small size and narrow corridors made it difficult for the teacher and myself to communicate with the students. In Prairie Vista's Technological Careers in Geography class, students from other classes were usually in the lab, which was disruptive and at times kept Mr. Clark's students from sitting together as a group. At times, students from other classes worked in the Hope lab, but the lab's spaciousness prohibited this from being a problem. At Riparian, the other students were strictly kept out of the lab.

One concern with any computer-based teaching is how to achieve and maintain student's attention in a laboratory setting, where distractions are one mouse click away. I discovered that it was relatively easy for students in Riparian's and Prairie Vista's lab to view web pages or Internet music videos instead of staying on task. Such temptations did not exist for the control groups, but I found it also to be dependent on the lab's furniture configuration. At Hope, most computers were spread

around the lab's periphery, allowing the teacher to see most of the screens in any one glance, effectively reducing the tendency to wander off task.

Requirements for Technical Assistance

Approximately 60% of my time and the teachers' time was occupied with answering questions from GIS-using students, compared to 30% of my time answering questions in classes using traditional methods. At no time did I witness a teacher grading papers or preparing for the next lesson in GIS-based classes. This time commitment is precisely why many teachers hesitate to use GIS—they typically only have one planning period per day in which to accomplish assessment and preparation.

Student-Teacher Relationships

All case study teachers displayed an excellent working relationship with their students. For example, the Technological Careers in Geography (TCIG) class is part of Prairie Vista's Educational Partners in Career (EPIC) program, meeting after school once per week. Students enrolled in TCIG partly because they wanted to take another class from Mr. Clark. Students often talked with him during class and in his office about internship and career opportunities and wrote him notes on the lessons I reviewed.

After considering his nearly 30 years of teaching, Mr. Stevenson remarked that his classes used to be comprised of a few superior students, a few at the bottom, and a large middle section who were bound for the state university. In the past few years, this middle section has almost disappeared, leaving two large groups—those who excel, and those who, in his words, were “clueless.” I observed, however, that Mr. Stevenson spent an equal amount of time with both groups. All teachers drew the line, however, at spending too much time on a smaller group of students that showed no

desire to learn. These students could very quickly monopolize the time of the teacher in the lab as they sometimes tried to do to mine. Conversely, I noted that several students in each class very quietly and efficiently completed their work, exploring data with the software and going beyond the assignment's requirements.

Student Background and Attitudes

Computer Experience

Prior computer experience greatly influences what students may learn in the GIS-based lessons. Some students finished editing the earthquake file in 20 minutes; others required a whole class period. When still others were not complete by the second day, the teachers and I told them to edit just a few earthquakes and delete the rest. By doing so, they would be able to understand the technical procedures. But, because they did not look at all earthquakes, the patterns would not be as evident and they would likely miss the purpose of the lesson—the pattern of global earthquakes.

Without good computer and data management skills, a student can become quickly lost in a GIS-based lesson. At Hope, for example, I observed a student assign “broncos” to the name of a spatial data file. He named the next one “bruncoss,” adding an “s” for each new file. Soon all files looked similar, which made it impossible for him to determine which file went with the correct analysis. Software problems ensued because students placed non-alphanumeric characters in their file names. Knowing the location of data was equally as important as the name. Students often did not understand the distinction between the location of files that they created and the location of the base data.

Tolerance and Flexibility

Toward the end of the semester, students seemed more comfortable with the software. They less frequently demanded that the software “should be able” to do a certain task, and expressed less frustration in the fact that answers are not going to be found without work—examining data and thinking about the patterns. The main factor holding a few students back from successfully tackling GIS-based projects had nothing to do with the software, but was that these students did not have the necessary listening skills. They tended to begin these units in a frustrated mode and stayed that way. These students often sat together in a group of four or five students, where the group situation seems to heighten, rather than diffuse, the level of frustration. Groups with three or more students usually had at least one student who contributed very little.

Most students were familiar enough with computers to know that they don’t always work the way they are supposed to. With only a few exceptions, students were patient and many attempted to solve problems themselves and used the teacher as a last resort. Only occasionally, when there were system-wide errors, did the process interfere with learning. Even then, a method to work around the problem was usually found, sometimes by the students. Because making errors is an effective way of learning how to work a system (Greif 1991), these difficulties contributed to overall skills and knowledge gained.

Some students in both the control and experimental groups were preoccupied with simply getting through the assignment, asking me repeated questions about whether an answer or a map was “correct.” In many of the lessons, more than one answer may be correct, and the students are given flexibility in the symbology and types of maps they produce. Some of these students became puzzled by the lack of a single correct answer. They are not accustomed to project-based, inquiry-based learning. This was particularly true of Grade 9 students, as recounted above in the

class at Riparian. GIS appeals to students' heightened sense of control when their teacher doesn't always know the answer. At the same time, it is a bit unsettling to students, because they want problems to have answers. As Cohen (1988) put it, "How trustworthy can knowledge be if it is constructed and not composed of facts?" I found that it is difficult to get students to be producers of information; they are too accustomed to being consumers. With GIS, these students, like the teacher, have a new role. The Grade 12 students, already enrolled in project-based advanced geography classes, were more willing to explore and investigate, particularly toward the end of the semester.

Thus, it takes time for students to become accustomed to a different style of teaching and learning. These observations support Dweck's (1989) assertion that learners' motivation depends on whether they are "performance oriented" or "learning oriented". Many of these students are "performance-oriented," more worried about the possibility of making an error than about learning. Concern about their course grade is paramount.

Age Differences

All case studies teachers commented that the Grade 9 students were much more comfortable with computer technology than the juniors and seniors. Future high school students should have the necessary technical background to use GIS. Whether they will have the necessary geographic background will be largely dependent on the availability of geography courses and qualified geography teachers.

Motivation

According to one teacher, "These students will sit like lumps, then you give them GIS, and they can't get enough. [...] Even [the] Internet doesn't engage them

like this.” Indeed, Mr. Stevenson wanted a focused activity for his unmotivated seniors during their last few weeks of school, so he gave them several Africa GIS modules. Students exhibited the most pride in their achievements when they believed they succeeded on their own effort, rather than because of the teacher’s assistance, or because it was easy. This supports the observations of Schunk (1996). Classroom observation showed that not *all* students were engaged, but case studies teachers and I noticed that the overall motivation level increased with the introduction of GIS.

From the county spatial analysis by the Advanced Geography classes, several consistent behaviors were noted. Mr. Clark commented that he had to “clamp down” on his students to “stay (focused on) the project” two or three times during the year, and one of those times occurred during the county social area analysis lesson with the control group. If he had not disciplined these students, the experimental group would have noticeably performed better on the lessons. There was “no problem” motivating the GIS students. The advantage of GIS was that, in this case, the GIS students finished faster and wanted more lab time. While waiting for the non-GIS students to finish (so Mr. Clark could start both groups with a new project at the same time), they explored other functions of the GIS program, which helped Mr. Clark “learn many new functions from [his] students.” The disadvantage was that the GIS students tended to get off task and explore various aspects of the program, causing some to lose sight of what the assignment was all about.

Ms. Eliot wrote, “You cannot measure interest or excitement to learn. I think the computer and the visual interaction is [sic] so important rather than the black and white copies we gave them in my [control group] class.”

Reactions to GIS

GIS augmented self-esteem and enthusiasm, which may increase learning. When students at Hope finished before the end of the class period, they used GIS to find their houses. Ms. Cessna's students also showed GIS to their friends who arrived in the lab from other classes.

During the last TCIG class, I asked the students what was the best and worst thing about GIS. "It's amazing!," said one student. Several students viewed GIS as a "helpful necessity" in assisting them with other projects, such as a map inside a printed report or in a PowerPoint presentation. Students' beliefs in the utility of GIS were still largely confined to the production of maps, rather than an analytical tool that could be used as a means to an end. Students said that GIS "made life easier" because they could label countries and other locations more professionally. Students were quick to point out that "any student could use GIS in their high school career." The three females in the TCIG class had no great fondness for the computer, but praised GIS. The males in the class tended to demonstrate more fascination for the computer, and they too thought the GIS experience was valuable. Most students reacted favorably to GIS, even those who claimed to dislike computers, recognizing that "a task given isn't always so difficult if you have the right resources."

The "worst" thing about GIS to these students was its "limited information about some things" and that it was "frustrating." These comments reflected the lack of an operable computer network, limiting students to the small set of sample data that comes with the software. Another disagreeable item was the difficulty in using the query builder to ask questions of the data.

I also asked students if their perceptions of geography had changed because of GIS. GIS was mentioned as "giving geography more respect" and "providing for more diverse careers" in geography.

GIS-based project results have a more professional feel to them, and students take the production of them more seriously. Linn (1997) discovered similar attitudes with students contrasting *Hyperstudio* with traditional methods. According to the teachers, the mere process of GIS fosters more analytical thinking, because it comes across in a more scholarly, sophisticated way. As Collins (1991) put it, there is “a kind of ‘authenticity’ associated with using [computer] equipment; for students, the technology represents the future (p. 28). In geography, in particular, computers are a novelty. They could be preferred for that very reason. This sophistication is not without its dangers—I noted that students have a tendency to view the computerized map as “perfect,” even when it might not be.

Students in these same classes were given a questionnaire at the end of the semester to assess their attitudes about the class, its tools, and about geography (Appendix A.31). One question asked students to rank the value of the tools that they used in the class from 1 to 7, including GIS, with “1” representing the most valuable. The mean ranking for the experimental group was 3.25 (n=36), significantly lower than the mean ranking for the control group (4.15; n=20). Thus, GIS students valued GIS to a greater degree. This supports the national survey’s finding that there is a large pedagogical difference between *using* GIS and *demonstrating* GIS in the classroom.

On the same survey, students were given the following scenario:

“Say you had an assignment to compare growth rates from 1950 to 1990 for counties across Colorado. Describe how you would complete this assignment, listing where you would obtain the data and how you would analyze it.”

In the experimental group, 23 students (63.9%) described how they would use GIS to solve this problem (n=36). Only 7 control group students (35%) included GIS in their problem-solving description. Students using GIS during the semester

understood the value of GIS in solving problems, and also could outline the major steps involved in solving such a problem significantly more than students who had only been shown a GIS. Most retained the skills they had acquired up to 10 weeks before, after only a few GIS-based lessons, and could repeat them without being forewarned. This demonstrates that some learning took place in these short lessons.

The survey also asked, “What things have you learned this semester that could be transferable to a job/career or college? Please cite at least three specific examples.” Students in the experimental group cited GIS 14 times, or 38.9% of all responses. Students in the control group cited GIS only 4 times, or 20% of all responses. Not only could students who used GIS during the semester apply it to a new problem, they could see the “big picture”—how it might apply to their futures. Skills mentioned by one include “How to make customizable maps, how to import things from the Internet, and I also learned to research a huge amount of data quickly.” Despite a wide variety of college and career plans mentioned—from marketing to accounting to natural resources—students saw the application of not only GIS, but geography, to these careers. One student wrote that “Geography, is much like Algebra, we study patterns and order. Except instead of numbers, we deal with people, the weather, topography, cultural trends.” Six out of eight students in the TCIG class specifically mentioned that they would use GIS to analyze growth rates across Colorado.

The Effect of GIS on Special Needs Students

In the teachers’ opinion, the top students “learn with any method.” Experiments indicated that GIS might benefit students with average and below-average skills more than those with above-average skills. One Hope High School student had multiple sclerosis, which prohibited him from writing. GIS proved

valuable with his geography lesson, because, with the help of Ms. Cessna and the student's aide, he learned how to run *ArcView* GIS software and print maps.

Another student, a 19-year-old Hope senior, had been held back for two years for low achievement. He became so interested in GIS that he visited me at my home late at night, asking for GIS assistance to please the teacher with computer-based maps for his advanced geography portfolio. Because it is a visual tool relying on graphics, GIS may be a good method of learning for students who are not ordinarily good readers. Another student in the experimental group had a "D" grade going into the GIS-based lesson on *The Hill*, and afterwards performed at "A" level. These examples seem to indicate that the amount of student interest in GIS has more influence on what they accomplish with GIS than computer background or prior academic record.

To test these observations, I observed how special education students worked with GIS. Ms. Wright, special education and geography teacher at Riparian High School, observed during Fall semester 1998 that many students of low to average skill levels became excited about geography only after the introduction of GIS. She commented that "most special education students hate computers because of bad experiences, such as the time they 'couldn't save' or 'couldn't print'." Although her students did not find the *ArcView* tutorial intuitive, they became quite proficient at GIS after completing the *Earthquakes Everyday* and *Africa* modules, citing graphics and step-by-step methodology as reasons for their enthusiasm. Because the special education students in the following semester did not respond as enthusiastically to GIS, the attraction to GIS by special needs students is not ubiquitous, but warrants further testing. Ms. Wright is convinced that special education students learn more geography with GIS than with any other tool.

Community Linkages

The case study teachers became more connected to the community in several ways. First, they designed lessons based on local geography. Second, they began gathering digital data from local sources, not simply from the Internet, but by meeting with city and county officials in an effort to obtain data. Third, they realized that supporting a GIS component in the curriculum would require funding, and thus increased their efforts to seek district, state, and national grants.

Through using GIS, the geography programs at these schools received recognition, particularly at Riparian High, where it has been in place the longest. The school was selected as the site of the three-year Earth and Space Science Technological Education Project (ESSTEP), coordinated by the Geological Society of America. Over 80 teachers from primary to university level from across the United States were trained there in science and geography technology. GIS projects at the school have also been the subject of presentations and workshops at the ESRI User Conference, Colorado Geographic Alliance, GIS In the Rockies, the National Science Teachers Association, the Arizona Geographic Information Advisory Council, and the National Council for Geographic Education.

Teacher Professional Development

GIS has influenced the professional development of each case study teacher, as evidenced by their increased enrollment in classes, number of workshops and presentations, attendance at conferences, and participation in research. Mr. Stevenson enrolled in a remote sensing course at the University of Colorado, Mr. Clark took a graduate course there entitled "Geography Teaching Materials," and after the case studies, Ms. Cessna left high school to pursue a principal's license and a Ph.D. in Educational Administration. Mr. Clark participated in the planning board

for A.P. (advanced placement) geography, and secured a grant where students could examine geographic aspects to Colorado legislative bills. Mr. Stevenson and I co-taught GIS institutes for teachers in numerous school districts and made presentations at GIS and education conferences in several states.

Looking at real data forces teachers as well as students to analyze geographic concepts more fully. Motivated teachers continue to learn and become closer to the subject matter, in this case, geography. GIS seems to increase teachers' affinity for geography. They are using the same tools as practicing geographers. However, these same teachers were enthusiastic about geography and education before the advent of GIS as well.

Teacher Attitudes and Characteristics

As Slater (1993) stated, the act of teaching is “a highly personal and somewhat idiosyncratic activity” and the “personality of the teacher has a strong influence on the style of planning and presentation.” Each teacher handled GIS a bit differently, even with lessons that were used in all three schools. First and foremost, each of the teachers practiced a great deal of self-assessment each day, reflecting what they could do more of, less of, better, or differently. Even though none of them were the only teacher of geography in their school, they were not bothered by doing something very different from the other geography teachers. Mr. Stevenson best fit the typical teacher responding to the national survey—one with over 20 years of teaching experience. Like the other respondents, he was quite familiar with geographic concepts, seeking a new approach to “finally” conduct “real spatial analysis” with his students.

Fitzpatrick (1998) identified two teaching requirements and two mindsets essential in instructing with GIS. The case studies showed that teachers were skilled

in the teaching requirements—computer file management, and in database concepts. The teachers also met the mindset requirements—they were comfortable with indirect paths for learning, where the endpoint may not be specifically defined, and comfortable with modeling open-ended learning in the classroom.

Not only did teachers progress during the year in their understanding of what a GIS is suitable for, but it was apparent that their questions about GIS differed substantially from the teacher at Hope who taught only the control group and had not yet been trained in GIS. While the control group teacher wanted to convert existing maps from textbooks into a GIS (such as those depicting the rise and fall of the Roman Empire), the GIS-using teachers wanted to input *new* data for new analyses. New teachers also tend to want to know what types of spatial data exist before starting a unit. Experienced teachers start with an idea for a unit, and *then* investigate how the data needed can be obtained.

Did the use of GIS change teaching style and philosophy, or were teachers drawn to GIS *because* of their teaching style? Each teacher stated that it was the latter. “My teaching style drew me to GIS in the sense that I believe in creative lessons that challenge kids,” wrote Ms. Cessna. Teachers attracted to GIS are those who stress critical thinking and analysis. Even though their teaching philosophy did not change, their teaching *methods* changed, as they changed in other semesters, because they “always seeking out new things that would be new tools for teaching students.” Mr. Clark worked with GIS extensively in college courses, yet Mr. Stevenson and Ms. Cessna, who found out about GIS in a conference and inservice (respectively), believed just as highly in its benefits.

Knowledge and Dedication in Uncertainty

Case study teachers were found to be extremely knowledgeable about geography, including its standards and themes. Mr. Clark's students finished seventh in the nation in the 1998 Geography Olympiad and ninth in 1999. Their offices and classrooms are full of maps and data resources. I noticed that these teachers read scholarly geographic literature—for example, Mr. Clark was reading Kunstler's *The Geography of Nowhere*. These teachers are experts, and their knowledge affects what they notice and how they organize, represent, and interpret information in their discipline (Bransford et al. 1999). GIS appears to have expanded their view of geography.

The teachers were also dedicated to geography, which was their prime motivation to implement GIS. Their efforts were successful as a result—"there is no satisfactory substitute for a teacher's knowledge and love for geographic inquiry" (Douglass 1998: 185). Using computers makes no difference unless students can reflect and have guided questions from a teacher who understands geographic analysis. These teachers do not view geography as a fixed body of information "out there," but that it is a worldview, *constructed* from analyzing spatial data.

Case study teachers cared about their students, both professionally and personally. They were not hesitant in giving their cell phone number out to their students, nor were they unwilling to stay after class for them or spend a few hours inputting data into a GIS-based lesson. The first thing they think of when they receive a grant is the student. For example, Mr. Clark planned to use grant money for an external hard drive for students to save their projects on.

It is said, "teachers teach what they know" (Douglass 1998). Studying these teachers, however, hinted that this is not completely true with GIS. The teachers did not understand the software completely, and expressed uncertainty about using it after

being away from it for a few weeks. They had never taught these units before (except at Riparian). Not only were the teachers using a problem-based method in their curriculum, but they adopted the role of problem-solvers themselves. If something did not work on the computers, they tried several methods to make it work. All teachers asked questions alongside the students and expressed enthusiasm when something new was accomplished or learned. They frequently looked at student work and offered encouragement.

Computer Skills

Bednarz (1995) stated that because every new technology has promised better motivation, instruction, and learning, teachers are wary of technology-driven change. By the time of the case studies, teachers were not wary of technology, but embraced it, even though it meant modifying their curriculum. The case study teachers were quick to state that they were not experts with computers. My observation confirmed that while they were not among the most highly computer-literate teachers I have worked with, they were committed to geographic technology, and were willing to learn new skills to enhance education. These findings support Yeaman (1993), who viewed computer anxiety as “phony,” stating that reporting about the anxiety only serves to perpetuate it. Mr. Stevenson, in particular, was a self-confessed avoider of computers until relatively recently, claiming that he was “one of the last teachers in my school to do my grades on the computer.” His message of encouragement to other teachers was, “If I can do it, so can you.”

According to Mr. Clark, the one thing that hinders the use of GIS in education is that most teachers do not have the ability to manipulate data. Mr. Asi (the second Hope control group teacher) believes “what stymies teachers the most is how to put data into GIS format.” To use GIS, teachers need as good an understanding of the

technology behind the computer as the case study teachers had, including the directory structure, network access, and capability. For example, saving files in a “student temporary” folder on the network as recounted above is an example of a situation that poses difficulties in sharing GIS-based lessons. Lessons cannot account for the differences in computer network configurations. Therefore, teachers will be required to make their own adjustments, and to do so, they need to understand computers.

Curiously, the network these teachers developed for technical assistance was smaller than for the acquisition of data and for professional development. Part of the reason may have been my close involvement with the teachers for technical assistance, yet they did not rely on me a great deal. They did not rely on the other case study teachers for this type of assistance either, even though each was aware of what the others were doing with GIS. This may be because of time constraints and the independent nature that they shared with respondents to the national survey.

Characteristics of Other Lessons

Case study teachers used technology and multimedia elsewhere in their curricula. Ms. Cessna’s and Ms. Eliot’s classes featured *Around the World*, a project where students “travel” around the world as reporters on earned money. The “money” is from points scored on their papers. They submit newspaper articles to their teacher, who is the “editor.” *Around the World* is a standards-based research environment that makes heavy use of Internet and CD-ROM atlas data. A student-generated PowerPoint presentation is a performance assessment tool containing their reports. Prairie Vista’s County Social Area analysis project is a combination of GIS, multimedia, and field work. The project became a reality through a National Geographic Society Education Foundation Grant for \$6440, co-written by Mr. Clark

and this author, which funded a printer, a global positioning system (GPS) unit, and a field trip.

Mr. Stevenson and Mr. Clark used textbooks but did not feel that the textbooks were absolutely necessary. Ms. Cessna did not use a textbook. All stressed field work. Mr. Clark took great effort to bring his students on field trips to the USGS and to the U.S. Bureau of Reclamation to see how GIS is used in the field. His students prompted the Reclamation staff to comment, “I didn’t know high school students could do this!” Mr. Clark took personal leave days to attend local GIS conferences and to go on “data collection missions” in the community. This showed that the long-term goal of using real-world data and doing analysis was more important to him than the short-term inconvenience of missing a few classes.

Ms. Eliot wrote, “I believe that computers are the future in teaching. Also I need GIS and other lessons using computer technology to keep students interested and motivated to learn.” These teachers used activities that capture the student’s attention during their teenage years, and that show the applicability of geography to many fields. Mr. Clark required students to plan pizza delivery service in Europe, using GIS and traditional maps to gather data and produce a final report. These teachers also prefer “hands-on” techniques whenever possible, as evidenced by a 10-foot-long scale model city that Mr. Stevenson constructs and floods each semester, as part of a natural hazards unit.

Dissatisfaction with Traditional Media and Methods

Case study teachers were united in their dissatisfaction with media and methods in textbooks, atlases, and on CD-ROMs. They were attracted to GIS because of its ability to produce customized maps for the themes of the teachers’ lessons. Critiques about traditional maps were that they may be unclear, are on

different pages, in different books, and are at different scales, requiring students to spend the bulk of their time with the media itself, rather than analyzing patterns and solving problems. For example, colors for plains, hills, and high table lands on textbook and atlas maps of Africa used by control group students were indistinguishable. The maps also contained a definitional error (“shrub” instead of “scrub”), and used point symbology that made it difficult for students to determine earthquake locations. Mr. Clark believed that there is just as much value in using GIS to create curricular materials that are more understandable and that cover the themes of the lesson, as using GIS in a laboratory setting. Indeed, many respondents to the national survey indicated that this is exactly what they use GIS for.

Focus and Flexibility

Case study teachers were flexible and patient not only with GIS, but the media they used for any lesson. They kept focused on the overall goal of *education*, rather than *instruction*. “It is less stressful if you know where you are going,” Mr. Stevenson told me. As an example, he originally wanted to include a lesson on copper in Africa, but the data were unavailable, so we switched the question to silver instead. In another example, the teacher had to wait six weeks between the time his students finished the *ArcView* tutorial and the time he was able to start them on the Africa GIS project. Instead of getting frustrated, he commented that GIS “you have to take it [GIS] in stages; it’s always a work in progress.”

These teachers understood that educational GIS required practices that are not typically acceptable GIS procedures. For example, a NOAA image of fires in Africa was 80 megabytes in size. I digitized 10,000 points using the image as a guide for ease of use on the network, bringing the file size down to less than 100 kilobytes.

Focusing students on the *pattern* of fires in the context of natural hazards in Africa was more important than adhering to the first-generation data file.

The Pursuit of GIS

Although all case study teachers emphasized teaching *with* GIS, rather than *about* GIS (per Sui 1995), they thought that GIS was worthy enough to be approached and discussed for its own merits—it was more than just a tool. One teacher said quite plainly that his “purpose [was] twofold—to introduce students to the basics of GIS and its capabilities, [and] second, to show them how standard areas of geography can be approached in a new way.”

Mr. Clark had wanted to use GIS for five years, so these projects were “realizing a long-term dream.” Mr. Stevenson added, “This project has been one of a great deal of work. Yet it has also been one of a great deal of payoff, in terms of skill building, the exploration of new technology, and new ways of teaching and learning. It has become quite a project. Certainly more than I ever dreamed it would be.”

Perhaps the strongest endorsement for GIS mentioned was not for what it did for the students, but for a teacher. Ms. Wright had accidentally fallen at Riparian and suffered head injuries. Her use of GIS represented the turning point, renewing her motivation and confidence to write grants and pursue research projects. She stated that “one’s self esteem increases by using a tool that seems difficult.”

Clearly, GIS has influenced the geography curriculum at each school. The amount of implementation falls at the far right end of the continuum (Table 3.1, p. 90), using it in more than one lesson in more than one class. The amount was stymied by a lack of technical support at Prairie Vista and encouraged by technical support at Hope and Riparian. Similar to the national survey’s results, fewer than 10% of students in each school were exposed to GIS.

Teaching with technology causes some to be concerned about “reverse adaptation”—the transformation of existing goals to accommodate a new technical means (Winner 1977). However, even in a GIS class, as opposed to a geography class (such as the TCIG class at Prairie Vista), case studies showed that goals still adhered to the national geography standards, emphasizing *doing* geography, not just learning *about* geography. In fact, GIS was repeatedly cited as meeting long-held goals in geography instruction. The common approach to learning GIS by these teachers was on a need-to-know basis. Each teacher knew enough about GIS to realize that one doesn’t sit down and learn the entire program in one day or one year. Rather, if a lesson needs a certain GIS function, teachers would then learn that function. Thus, GIS did not guide the lessons. The lessons, based on curricular goals, guided how GIS was used.

Plans for Expanding the Use of GIS

Similar to teachers responding to the national survey, all four case study teachers had future plans for expanding GIS use in the curriculum. Mr. Stevenson planned to implement a lesson where students would plan a light rail line through the Denver metropolitan area, analyzing physical geography, the existing transportation network, and demographic characteristics. He also intended to expand *The Hill* unit with digital orthophotoquadrangles so that students could view houses and businesses in the city’s neighborhoods, and with digital elevation models for a three-dimensional view. He would also like to change the high school curriculum by offering a GIS class co-caught by a technology specialist and a geography teacher. This class would emphasize both the technological and geographical aspects of GIS.

These teachers also worked to expand the use of GIS within their school, to other schools, and to other disciplines. Said Ms. Cessna, “I have encouraged other

teachers, held an inservice day, shared lesson plan ideas, [and] worked with others during planning periods. [Now] it's up to [them] whether they want to keep the software [after I've left the school]." As the survey found, these teachers act as "change agents" (Rogers 1993), because through interpersonal communication in their professional activities, they promote diffusion of the technology.

At the end of the academic year, each of the three case study teachers was asked, "Was GIS worth it?" All responded quickly with a "Yes." Ms. Cessna qualified the answer with a "I think so," with an emphasis on the "I." This underscored her belief that not all teachers will deem GIS worth the effort, even though she did. The case studies showed that GIS implementation is most definitely an effort. All teachers had endured technical problems. One had professional differences with other faculty members that came to a head by using GIS. All three teachers had to commit their own time outside of class to make GIS work successful.

Assessing the Learning Process

Progress Over Time

Experimental students' technical abilities improved throughout the lessons, even though each lesson was only three to ten days long, and students typically used GIS for less than two months during each semester. When starting a typical unit, students could only create one view in a class period. After three days, they could compile multiple views and create multiple layouts per class period. The quality of the maps increased as well, showing pride of ownership. The cartographic components of the layouts improved, including the spacing and sizing of maps, legend components, and color selections.

Furthermore, students' thinking was pushed to higher levels, progressing from query to analysis. The difference was noted in their questions from "where is the

store?” to “where should I locate a new store?”, and from “show me the pine trees,” to “which trees are ready to harvest?”

Most significantly, students working through *The Hill* project began to pair maps in the layouts with logically comparable themes, such as median income with age. Therefore, while working through the modules, the skills and analysis required became progressively more advanced. Students did not want to waste time creating maps they did not need. Thus, they behaved like project managers, developing an essential workplace skill.

One student displayed spatial awareness and software skills by creating custom point symbols for her house, her boyfriend’s house, the elementary and middle school she attended, and her grandmother’s house. Students learned that a map can be a dynamic entity that they could ask questions of. As found in the experiments, students using GIS work with the maps as analytical tools with much greater frequency than students using traditional methods, which may indicate increased spatial reasoning.

Multiple Skills, Multiple Disciplines

Case studies indicated that requiring students to use GIS obligates them to develop several other skills simultaneously with GIS skills. These include geographic skills, data skills, database skills, and computer skills. Students did not learn all software skills from the *ArcView* tutorial, so they encountered new problems during the lessons that required them to construct their own solutions.

As the literature review indicated, students broadened their view of the world. While looking at the screen containing two separate map themes, one student said, “I’ve combined sociology and geography.” At Riparian, a student constructed a map using *ArcView* for a French class. At Hope, many students chose GIS to construct

maps for their “Abject Poverty” and *Around the World* lessons. Using themes such as drugs, land mines, and deforestation implied that students had to learn the program well enough to go beyond printing an outline map to loading the appropriate thematic data and selecting the attributes to map. Geography proved to be a good model for students to learn how to integrate interdisciplinary information.

Traditional versus Problem-Solving Knowledge

The process of making maps with GIS required students to view information with greater frequency. The lesson structure, each new class period, and even software crashes required students to load and re-load tables and maps. For example, students became more knowledgeable about the absolute and relative locations of countries and cities in Africa and neighborhoods in their own city. As supported by the standardized test experiments, this seems to indicate that GIS does not only teach problem-solving skills, but also traditional locational content knowledge.

Gersmehl (1992) suggested that for some topics, a straightforward *deductive* approach works best: “Here’s the theme, and this is how we apply it in the real world.” But for many ideas, an *inductive* approach is more effective:

“Here’s a story, a situation, a problem: let’s examine it for awhile; here’s another one, a little bit different.” ... The deductive approach usually gives results more quickly, if by “results” we mean correct answers on tests that measure short-term recall of factual material. But the inductive approach can have a much more lasting effect, because it compels the student to apply the tools of analysis and to seek the theme wherever it may be hiding in the welter of everyday experience” (p. 119).

The inductive approach was threaded through many of the GIS-based lessons. One reason the experimental data may have netted such mixed results is because, as Gersmehl implies, its benefits are difficult to measure with traditional tests.

In these classrooms, I observed much evidence of student-centered, problem-based learning (pizza project), authentic practice (social area analysis), and alternative assessment (*Around The World*). I found GIS to be as much a process as a technology. Students started by thinking about a topic, making a map of it, exploring patterns, changing the analysis, asking a new question, and repeating in an iterative, exploratory sense. Choices diverge from a vague beginning point. The process is similar to what Slater (1993) advocated—that learning should involve raising questions, processing data, and developing generalizations. The progression from questions to generalizations is crucial as a strategy so that geography begins to make sense “as a network of ideas and procedures, not a heap of isolated facts” (p. 60). I noted that the teacher’s role in this scenario was framing the basis of exploration, helping steer the investigations, and providing some technical assistance.

Difficulties in the Learning Process

GIS shares the same problem as is present with other proprietary computer software—students cannot make up for missed classes by doing the work at home. A student approached Mr. Stevenson with a blank expression: “I wasn’t here yesterday or the day before.” The student was sent to a group that had already started, but faced a challenge to catch up with the rest of the group. It is difficult for a student using GIS to miss a step and still understand or be able to complete the lesson, because GIS-based projects usually require data files from the missed step.

Two students each said that they needed help—“I was stuck for 15 minutes yesterday.” The teacher responded, “Why didn’t you say something yesterday?” The teacher faces the challenge of how much time to spend with students who are far behind the others. Peer mentoring was encouraged by all teachers and worked

especially well at Prairie Vista, where the problem-solving approach of the IB curriculum seemed to have a positive influence on student communication.

One Africa lesson focused on natural hazards, to show how the previous topics in the unit “fit together in the real world,” according to the teacher. However, students were not able to complete the last lesson because of time constraints and the availability of the computer lab. When a portion of a lesson is not implemented, particularly GIS-based lessons that are dependent on previous GIS experience, the effectiveness of the entire unit is hindered. Certainly, this is true of all carefully sequenced teaching materials, but the additional time required by GIS-based lessons over lessons using traditional media makes it more likely that the lesson will not be completed unless adequate time is given in the curriculum.

Different Rates, Different Routes

Observation made it clear that experimental group students learned at different rates, and through different routes. This is what Vygotsky (1978) termed “multiple zones of proximal development,” and presents a challenge for teachers, parents, and administrators to rethink their expectation that the educational system must teach the same thing to each student.

The spatial analysis posttests showed that many students had exhibited progress in spatial thinking:

“(1) This is the best spot, since I can get away with developing next to the high school [because of commercial zoning], catching a high income area and not being in close proximity to another Spiffy’s. (2) Again this is a high school zone with commercial zoning, fairly busy streets and is proximal to two high income areas. (3) High income area, commercial zoning, fairly busy street and easy access for teenagers who are in the mall anyway.”

However, other students were still choosing locations based on what they “felt to be right,” rather than analyzing the maps and variables:

“I chose my top 3 location [sic] due to the location of the school. My location is not too far away from the high school and not too close. To me Median Household Income is not an issue but zoning is.”

The Influence of GIS on Learning

Because students selected their own variables for *The Hill* and for the County Demographics lessons, they had much more ownership of the project with the GIS component added. Switching from a didactic to a more project-based approach gives students more autonomy in their learning, similar to what happens with other computer work (see David 1992).

The process of producing final plots with GIS caused experimental group students to look more carefully at the attributes they chose. Until they became comfortable with the process, they considered their choices more carefully to avoid having to make more maps than were needed. By the time they became comfortable with the mapmaking process, students had spent quite a bit of time thinking about attributes so that as they progressed, the level of concentration on the maps increased.

Students in the experimental group demonstrated a better integration between the process of *making* maps and the process of *analyzing* the maps. GIS encouraged more thinking about how attributes affected the situation on *The Hill*. Discussions with the students revealed that, while making maps, they were thinking ahead as to how they would answer the questions. At least from these observations, there appeared to be processing on a deeper level of the information at an earlier stage of the project with the use of GIS than was the case with the non-GIS students.

According to Mr. Stevenson, students using GIS produce work of higher quality across all grades and units than non-GIS students. C-grade papers using GIS are better than C-grade papers by the non-GIS students, implying that the teacher's expectations have increased. Because GIS made it easier for students to produce maps, they are expected to spend more time in analytical thinking. Students appeared to be able to uncover a greater number of relationships between attributes in the limited time they had for each lesson. Understanding these additional relationships leads to a better understanding of how physical systems and human systems are connected (Africa and Earthquake lessons) and how demographic and housing characteristics are related (*The Hill* lesson). GIS takes advantage of a variety of images and themes, which may allow for more connections to be made. Students can understand the Earth by making a picture of the Earth that makes sense.

The potential for increasing learning within curricular time constraints attracts teachers, but most teachers shy away from GIS because of its overall time requirements. It is interesting, then, that the case studies point to a GIS advantage in doing *more* in *less* time. However, this advantage can only be realized *after* teachers have made the initial investment in GIS.

The Institutionalization of GIS

"Thanks Joseph! I could not have done this without you!," Ms. Cessna wrote me following the *Pump It* oil lesson. While I appreciated her kindness, its message has dire implications for GIS in education—would these lessons have been implemented if I had not been involved? Furthermore, what would happen to GIS-based learning if Ms. Cessna, or one of the other teachers, left the school? Research on innovation suggests that the more compatible that ideas are with the existing values and norms of a social system, and particularly to the person using the

innovation, the more likely it is that they will be adopted (Rogers 1995; Powell 1999). The case studies indicate that GIS has been fully adopted by the studied teachers—it was consistent with their teaching philosophy, teaching style, and affinity for the subject. If any of the three teachers moved to a different school, GIS would move with that teacher. Institutionalization at Riparian and Hope also suggests that it would remain at the original school as well if the teacher left. GIS at Prairie Vista would most likely cease if Mr. Clark left, because of the lack of administrative and technical support.

Key to the institutionalization of the Riparian High School GIS program was the careful, phased approach to implementing GIS into the curriculum. Rather than making massive changes to proven lessons, the implementation has been taking place slowly. The phased inclusion of the projects allowed improvements to be made and tested, and has allowed the selection of existing lessons where GIS would be the most effective. Despite this, it was not until other teachers in the school were trained via a technology grant written by Mr. Stevenson and this author during Fall 1999 did GIS institutionalization become probable. Hope's implementation was much more rapid, but institutionalization did not seem likely until the school district received its second National Geographic Society grant. Encouraged by the grant's training sessions, more teachers in the school began using it. During Fall 1999, these additional teachers in the school *did* keep using GIS after Ms. Cessna had left.

Sustainable projects—those that can be modified and re-used—are also important to the institutionalization of GIS in education. After the original project is created, GIS allows for relatively easy expansion and revision. Sustainable projects are important particularly with GIS because of the large "up-front" time commitment required to gather and load data, create lessons, test computer-based instructions, and configure computer systems. Processing vector and image data for the Africa

project required over 40 hours. Spending this amount of time on a lesson that would only be used once would not be a wise use of time for computer lab managers or teachers.

Comparing educational implementation of GIS to adoption by other users examines whether GIS in education is a “special case” as is so often claimed, or whether it shares characteristics with other GIS users, such as in local government (as examined by Budic 1993). Factors found to be important in the case study teachers’ decision to use GIS included personal factors and organizational factors. Personal factors included, first, a perceived advantage of using GIS over other methods for certain lessons. Perceived advantage was important to non-educational users as well. Although the teachers perceived that they were doing something on “the cutting edge,” they did not use it for this reason. Rather, they used it because they believed it would enhance learning. Second, unlike local government users, GIS was not found to be compatible with these teachers’ previous computer experience, particularly for Mr. Stevenson. Most were truly learning something new. Similar to Budic’s study group, computer related anxiety did not considerably affect decisions about using the GIS technology. The other factors—exposure to GIS technology, changes in communication behavior and networking, and a positive attitude toward work-related change, were important to both the case study teachers and the non-educational users studied by Budic. Unlike local government users, teachers used it despite little direct incentive or support from the administration. Teachers *did* receive personal and professional benefits, however, because they published papers, made school board presentations, received grants, began consulting, spoke at conferences, and received professional recognition.

Audet and Paris’ (1997) GIS implementation model, used in analyzing the national GIS survey (Figure 3.15, p. 155), can be instructive in analyzing the case

studies as well. They described institutionalization as programs that had a “well-developed educational context and were likely to continue even in the absence of the program initiators” (p. 294). Riparian and Hope had reached the “institutionalization” phase under all model components (software acquisition, equipment, data development, professional development, and educational context development). Prairie Vista was still in the “development” phase for software, hardware, data, and educational context. It achieved the institutionalization phase under professional development because of Mr. Clark’s software skills. The model describes the case study schools quite well, particularly in terms of showing that GIS requires continual effort in each phase—for example, gathering data and developing lessons.

Comparing Case Study Schools to Tenets of Educational Reform

These schools shared the four characteristics identified by Anderson (1995) as being engaged in educational reform—integrating themes in the subject matter, teaching for understanding by focusing in some depth on major concepts rather than covering a great breadth of detail, making connections between subject matter and its applications, and reaching all students with rigorous content and attention to critical thinking. Putting the reforms into practice proved a difficult task, involving months and years, not a few days. Commitment over the long-term shows that teachers believe GIS is worth the effort.

Through GIS, all case study schools exhibited trends in Collins’ (1991) model of schools that have adopted computers (Table 5.1). I saw no evidence of competitiveness. GIS fits well with the trend of integrating visual and verbal thinking but may hinder those with visual difficulties or non-visual learning styles. Coaching implies the recognition and acceptance of the value of differences among learners.

Table 5.1. Eight Major Trends in Schools That Have Adopted Computers
(from Collins 1991).

Trends	
From	To
Whole-class instruction.	Small-group instruction.
Lecture and recitation.	Coaching.
Working with better students.	Working with weaker students.
Less engaged students.	More engaged students.
Competitive social structure.	Cooperative social structure.
All students learning the same things.	Different students learning different things.
Primacy of verbal thinking.	Integration of visual and verbal thinking.

Comparing the case study schools against an *integrated* reformist and technology model (Bourne et al. 1995) shows that the case study schools met reformist criteria (Table 5.2). The only criteria not met is that students are not yet using GIS in conjunction with Internet communication tools (as some survey respondents indicated they do), although they are using the Internet to acquire data.

Table 5.2. Alternative Educational Model with Implications for Technology (from Bourne et al. (1995)).

Alternative Educational Model		
Lecture Model	Alternative Model	Technology Implications
Classroom lectures	Individual exploration	Networked PCs
Passive absorption	Apprenticeship	Requires skills development and simulations
Individual work	Team learning	Benefits from collaborative tools and e-mail
Omniscient teacher	Teacher as guide	Relies on access to experts over the network
Stable content	Fast-changing content	Requires networks and publishing tools
Homogeneity	Diversity	Requires a variety of access tools and methods

Pedagogical Approach

New and Existing Lessons

GIS was used in two ways in the case study schools—as a tool to create new lessons, and to modify existing lessons. GIS changes the way a lesson is taught, and what students learn from the lesson. According to Mr. Stevenson, adding GIS to *The Hill* “led to a much better project than was envisioned when it was first created.” It was simply not possible to analyze all 60 demographic and housing variables, 1970 and 1980 census data, nor data at the block-group level using traditional methods. With GIS, students could review a larger data set, not as an end in itself, but to be better able to make their point.

GIS not only changed the number and type of maps that the students prepared, it altered teaching and learning of entire projects. For example, in *The Hill* project, the number of variables that could be mapped and analyzed in one week was limited to about four variables using hand-drawn maps. GIS increased the amount and the types of data available to students. Rather than giving the students four variables, it was now up to the students to decide which of 60 variables supported their position. If a variable did not exist, the students were able to create it using the table calculation function. The paper-and-pencil maps were replaced by *ArcView* layouts, which permitted time for analysis without extending the project time. Because a greater number of variables could be mapped faster and more completely by the experimental group, the depth of thought behind answers improved.

Style of Instruction

The national survey clearly illustrated the variety of styles that are possible for GIS-based lessons. This ranges from detailed step-by-step procedures to brief oral assignments at the beginning of class before turning students over to the computers.

Case studies showed that students starting with GIS need to be provided with specific step-by-step instructions, and it is critical that they follow the directions precisely. For example, if a student is in the wrong window, the graphical user interface changes, and the instructions don't make sense. Ms. Cessna commented that students "need some structure; we can't turn students totally loose. They don't know what variables to analyze, especially at first." Students tended to overanalyze the instructions. Mr. Stevenson told the students, "Do what the directions say, not what you think they say." His commitment to this method was magnified after he began training other teachers in the use of GIS, finding that they, too, needed the step-by-step procedures when beginning, even computer-literate teachers. The teacher's hyperbole that he is "answering 90,000 questions in 15 minutes" reflects the importance of the teacher's guidance, particularly at the start of a new GIS-based unit.

All case study geography lessons followed the step-by-step model except those in the TCIG class, where the primary goal was to teach *about* GIS rather than *with* GIS. An example of the teacher's loosely-structured lessons was, "Access four variables in four different U.S. cities. Make a chart of these variables and compare them."

The danger in creating lessons containing many step-by-step instructions is that they quickly become quite lengthy (see Appendix A.10 and A.11 for examples). This was evident by the sighs of dismay that I heard when we passed out the *Earthquakes Everyday* unit. This led to an avoidance of reading the procedures. One student's comments reflected the cumbersome nature of the directions: "It [the process] is easier than the directions." I found that the great majority of the student's questions arose not because of software or hardware problems, but because they had not read the directions.

Teaching with GIS requires a choice about how much data preparation the teacher should do before giving the students access to the data set and lesson. The choice depends on the time allowed for the lesson, the background of the student, and how much control the teacher wants to give the students. Either the teacher creates the data set and gives it to the students, or the students create everything from scratch. Under each, the teacher still “sets the stage” but the students “act out and write the play’s ending.” Ms. Cessna’s approach was to “put structure in the lesson but [leave] room for the students to use the variables of interest to them.”

GIS, unlike other interactive technology, does not have a non-linear organization that can be accessed randomly. Certain things in GIS need to take place before other things—for example, the user needs to decide what data to analyze, where it is located, what scale it should be analyzed, and display and analyze it. Specific tasks within a GIS can be performed usually by two or three different methods, but if these options were included in the step-by-step lessons, it would add unnecessary text and confusion. As students became familiar with the program, they often discovered these alternative methods on their own.

Mr. Stevenson’s pedagogical approach was not to simply add something to the curriculum, but to “replace something and do it better with GIS.” He made sacrifices in his courses by dropping some lessons, but he believes that the “trade off is that learning is better. [The] skills will last longer than some things I was doing before.” His approach to GIS implementation was to emphasize the tools at the beginning. As the students become more comfortable with the tools, the amount of content can be gradually raised. In this way, the students are not being overwhelmed both with learning advanced content and a new set of tools simultaneously.

One teacher commented that “GIS provides a creative method of learning. It can also be a means of providing information itself. A GIS can store an enormous

quantity of information.” All of the GIS-based lessons illustrated that fact. However, is there, as Postman (1992) wrote, a tendency to value information over reasoning? All of the teachers emphasized reasoning and analysis over information in their GIS and non-GIS-based lessons. A few students seemed enamored by the fact that they were examining thousands of mines in Africa at once, for example, but did not spend an extraordinary amount of time browsing through the data.

Assessing GIS from Case Study Analysis

Assessing Teaching and Learning

Means and Olson’s (1994) five contributions of technology to teaching and learning can be tested against these case study observations. First, their statement that technology encourages teachers to present more complex tasks and material was supported by my observations. Adding a historical component to *The Hill* project and the *Pump It* oil lesson to the energy unit are a few of many examples. Second, technology supports teachers in becoming coaches rather than dispensers of knowledge, which was certainly evident in the manner in which teachers interacted with the students. The authors also mentioned that the introduction of technology was not the driving force in creating this kind of teaching style. Through the interviews, it was clear that the teachers were *drawn* to GIS because they had already adopted the constructivist, inquiry-based teaching style as their own. Using GIS further encouraged this type of teaching.

Third, the use of technology increases teachers’ sense of professionalism and achievement, which has been demonstrated in this study by the professional activities in which teachers have become engaged. Fourth, technology can motivate students to attempt harder tasks and to take more care in crafting their work. Students are attempting to do things that practicing professionals do after much

more training (albeit on a simpler level), because nobody has told them they “can’t”. Experimental group students were almost always more meticulous about their work—striving to “do more” with each lesson than control group students. Fifth, using the technological tools of the professional community adds significance to school tasks. I found that students believed that using the same tools found in the workplace made the projects look more official and realistic, and therefore, more important in the students’ eyes. One student told me, “We’ll never quit using technology and go backwards. These are life skills, not just academic skills.” I was quite impressed to hear a 17-year old student talking about “life skills!”

Assessing Lessons

These GIS-based lessons matched the “big six skills” approach advocated by Eisenberg and Johnson (1996). Together, these skills form an “information problem-solving process,” and include defining a task, identifying the types of information needed, developing a plan for searching for information, locating the information, determining the relevance of and extracting the useful information, organizing and communicating the results, and evaluating the process and product. The lessons were weakest on the evaluation phase.

The national geography standards team stated that “the power of a GIS is that it allows us to ask questions of data” (1994: 256). This was found to be the case in all three schools. GIS is one of the few tools that allows the student to follow through on “what-if” questions. Time after time, students asked, “what if I looked over in this area, how would the variable change?” or “what if I looked at different variables instead?” The teachers and I showed students how to change the mapped variable, and the classification of the variable itself from, say, a five-class map to a three-class map. For example, some students examining earthquake magnitudes were intrigued about the

depth of earthquakes related to the proximity to plate boundaries. Some even theorized that epicenters would be deeper near subducting plates, and then investigated this as a new problem not asked in the original lesson.

If the project includes the data under scrutiny, students can follow through on “what-if” questions. Being able to answer questions while the inquiry process is active is one of the biggest advantages to using a GIS. For the control group, the student would have to break away from what he or she was doing, go to the library, conduct research, write down the data, and attempt to map it in comparison to their other variable. By this time, the initial enthusiasm is likely to have waned.

Thus, there are many tangents that an investigation using GIS can take, and the problem could change as information is found. This works well if teachers do not rigidly adhere to assessing only the printed lesson questions. If they do, students feel disinclined to do their own investigating because they won’t be able to complete the written assignment. In the case studies, students did not have much freedom for exploration because of time constraints and the availability of the computer lab. Thus, educational constraints, rather than software or hardware constraints, limited GIS’s effectiveness. This illustrates the “ill-structured problem” promoted by advocates for problem-based learning. Students need more information than what is initially presented to them. As illustrated by the lessons described by national survey respondents, there is no fixed formula for conducting the investigation, and there might not be any single “right” answer (Stepien et al. 1993). Depending on the questions the students asked, the students did not learn exactly the same thing.

A different way to assess the effectiveness of GIS is against a model of reformist instruction. GIS in the case studies schools met each qualification of reformed instruction (Table 5.3). Students seemed used to the teacher’s role as facilitator from working with the teacher on other lessons. The only instruction that

cannot be classified as completely “reformed” in the case studies was the group versus individual work, since some students did work individually. However, the fact that the teachers felt comfortable with a variety of learning configurations in itself was evidence of reformed instruction.

Table 5.3. Comparison of conventional and reformed approaches to instruction
(based on Means 1994: 6).

Conventional Instruction	Reformed Instruction
Teacher directs.	Students explore.
Instruction is didactic.	Instruction is interactive.
Students receive short blocks of instruction on a single subject.	Students perform extended blocks of authentic and multidisciplinary work.
Students work individually.	Students work collaboratively.
Teacher is knowledge dispenser.	Teacher is facilitator.
Students grouped by ability.	Students grouped heterogeneously.
Students who have demonstrated mastery of “the basics” work on advanced skills.	All students practice advanced skills.
Students assessed on fact knowledge and discrete skills.	Students assessed on performance.

I assessed all GIS-based lessons for this research against constructivist principles itemized by Savery and Duffy (1995)(Table 5.4). Lessons used real-world data in an authentic, problem-solving, complex manner, but provided little opportunity for reflection and for testing ideas against alternative views (except for *The Hill* lesson). Usually, time constraints and the step-by-step instructions precluded most students from being reflective about how and what they were learning. These case studies illustrate active pedagogy, a technique recommended by many educational researchers and practitioners (for example, Moser and Hanson 1996; Harmin 1994). They fell short in one item that active pedagogy advocates—again, helping students

reflect upon their learning. The only exception occurred in the oral and written end-of-semester surveys.

Table 5.4. Instructional Principles Deriving From Constructivism
(based on Savery and Duffy 1995).

Principle	GIS-Based Lesson Assessment				
	Fails 1	2	Meets 3	4	Exceeds 5
Anchor all learning activities to a larger task or problem.				●	
Support the learner in developing ownership for the overall problem or task.				●	
Design an authentic task – to engage in scientific discourse and problem solving.					●
Design the task and learning environment to reflect the complexity of the environment they should be able to function in at the end of learning.					●
Give the learner ownership of the process used to develop a solution.			●		
Design the learning environment to support and challenge the learners' thinking.				●	
Encourage the testing of ideas against alternative views and alternative contexts.		●			
Provide opportunity for and support reflection on both the content learned and the process.		●			

These units were also assessed against Hill's (1994b) concerns about two patterns of instructional materials in geography—an over-reliance on textbooks and an increased use of disconnected materials without a unifying scope and sequence. GIS instructional materials are not found in textbooks. There is no unifying scope and sequence for materials developed by this author nor by most other lesson developers. Lessons are largely developed by individual teachers, rather than a research group working in a combined effort.

Bednarz and Bednarz (1995) identified four stages in which students acquire skills: Awareness, understanding, guided practice, and implementation. Students did not fully implement GIS skills, because they did not have enough opportunities to use them in these classes. Rather, they were at the “guided practice” stage, where they are able to use the software with guidance from a teacher or a step-by-step lesson.

Students in both the control and experimental groups exhibited skills mentioned in the national geography standards—they asked geographic questions, and acquired, organized, and analyzed geographic information. However, even though students learned *how* to perform spatial analysis, it is not completely clear that they knew *why* the phenomena they examined were important.

Summary

Means et al. (1993) classified software as tutorial (demonstrations), exploratory, application (such as databases and word processors), and communication. Students and teachers experienced GIS in the case studies as all of these. GIS was accessed as a graphics interface, an organizer of data, a producer of data, and a problem solving technology. This multifaceted nature of GIS posed difficulties for testing the effectiveness of GIS using standard empirical experimental methods. Case study research supplemented the experimental data with evidence that students using GIS make spatial connections more frequently and better than students using traditional tools, particularly those who perform at average and below-average level.

The case studies hinted that two forces may act simultaneously—GIS software allows for more creativity, but students are more creative to begin with on the computer. Students communicate using computers, are entertained by them,

and obtain information from them. Computers have been a part of their world during their entire school careers. Because GIS requires the manipulation of graphics, charts, maps, and (especially) data, it gives students a fuller practice of the array of computer tools than spreadsheet, presentation, or desktop publishing software alone. Because it involves aerial photographs, field data, satellite images, and maps in a real-world problem-solving environment, it provides students with an idea of the complexities of the world in which they live, and usually of their own communities. Students wrestled with data relevance and data quality, identifying relationships and drawing interpretations. Students were given a great amount of data, but most of them effectively transferred data into information, knowledge, and learning. They were not just “running GIS commands.”

Case study teachers adopted GIS because it introduces technology to the students and to geography, provides a way to address the geography standards, and matches their constructivist teaching style. These teachers were flexible in the uncertainties involved with using new technology, but were accustomed to multimedia and examining new methods of instruction. GIS increased the teachers’ ties to the surrounding community and to their own professional community. Similar to the national survey respondents, they planned to expand their use of GIS in the curriculum. Teachers use technology, including GIS, in many different ways. They recognized that GIS is not the only tool for learning, but believed it was too valuable *not* to use it, despite the difficulties involved.

Case study teachers modeled the lifelong learner for the students. Their enthusiasm for learning demonstrated that learning has a purpose other to complete an assignment and get a grade.

These case studies leave no doubt that inquiry-oriented learning with GIS can be difficult and time intensive. Although the computer lab manager’s involvement

was found to be critical, overall computer issues were secondary to the time required to create and maintain lessons and data, structure of the school day, school politics, and spatial thinking.

GIS increased student motivation for geography, altered communication patterns with fellow students and with teachers, stimulated students who learn visually, and reached students who are not traditional learners. Although students' acquisition of content and skills progressed throughout the semester, they learned at different rates and the resulting content and skills were different for each student. Inquiry-oriented learning through GIS requires teachers and students to tolerate uncertainty, take risks, and to change their traditional roles.

GIS found a natural home in the IB curriculum, which stresses the nature of geography, spatial decisions, spatial processes, perceptions, interrelationships between human and natural environments, current events, spatial patterns, and the application of the tools and techniques of geography. The county social analysis lesson easily fit with the urbanization theme, and *Earthquakes Everyday* fit in with human responses to natural hazards. IB students performed better on spatial analysis tests and standardized tests than did the students in the other schools. However, consistent with the national survey's results, the changes brought by GIS were also evident in standard beginning and advanced geography classes at Riparian and Hope High Schools. Like the experiments, case studies found no major differences between students and teachers between these schools. Technological and political problems at Prairie Vista were the most pronounced.

While learning with GIS offers unique challenges, it fit established models of educational reform. The teachers' commitment to geography, technology, and education encouraged the initial implementation of GIS in the three high schools. Content standards and grants for equipment and training ensured its eventual

institutionalization in two of the schools.

Studies of human cognition indicate that broad, well-organized knowledge is crucial for building on what has already been learned and for problem solving (Glaser 1984). The case studies showed that one of the chief constraints on GIS learning is not hardware or software, but the spatial perspective of teachers and students. Because the case study teachers had well-developed spatial perspectives, they were able to take GIS quite far in a short amount of time. Most students lacked this spatial perspective and were uncomfortable with the problem-solving style of learning of which GIS takes advantage. Some even lacked the vocabulary to explain spatial patterns of geographic phenomena. In the words of Mr. Clark, “Unless one has a spatial perspective, it [GIS] isn’t teaching geography.” This, combined with time constraints, limits the effectiveness of GIS in these classrooms.

Having analyzed the implementation and effectiveness of GIS in high schools on a detailed, local scale, the next chapter summarizes the present status of GIS in American secondary education, analyzes future influences on GIS, discusses implications of this study, and makes recommendations and conclusions.